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Energy price risk and the sustainability of demand side supply chains

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HIGHLIGHTS

- Energy is an increasingly significant production input due to rising and increasingly volatile prices.
- Technical risks from volatility in prices can impact the stability of individual firms and their supply chains.
- Extended temporal commitments in energy supply contracts reduce the flexibility of firms in managing price changes.
- The capacity to transfer price movements through the chain is reduced due to embedded understandings.
- Some key inputs, such as energy, have more significant and differentiated impacts on different firms' performance.

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ABSTRACT

Energy is a critical input for production industries. As production becomes increasingly fragmented the management of inputs along the supply chain is a significant factor to stability and the competitiveness of the individual firm and the wider chain. Sustainable supply systems will require changes in how energy is managed particularly to ensure energy security. Rising and increasingly volatile industrial prices create technical price risks to individual firms and the supply chains they are within. A comparison is made between the management of metal and energy price volatility in the intermediate metal processing industry (IMP) in the West Midlands, UK. Results indicate significant variance between the management of price risks from the inputs due to the structure of the supply market, the political-economic context of energy as a carbon source and industrial conventions within the sector. Interdependence between economic actors in the demand-side supply chain can generate risk to the competitiveness of the firm and supply chain from the ability to transfer, or share, price changes in energy inputs through the supply chain. This is an important aspect of energy security in demand-side chains that threatens the sustainability of industrial activity.

1. Introduction

Energy security takes a holistic approach to the systems of energy supply and demand. The consumption of energy is an important, and increasingly relevant, aspect of energy security. Energy security is progressively challenging the competitiveness of national economies, but is also a sector-based and firm level issue. For countries, energy security is particularly important for energy intensive economic activities that play a critical role in advanced manufacturing supply chains, for example aerospace and automotive, and account for 70% of industrial energy use [1]. At the firm-level energy security and related volatility enhances uncertainty and may undermine investment in capital equipment and research and development. As the energy environment changes and low cost, stable and sustainable energy inputs are not guaranteed, the interdependency of energy and the performance of production systems, and the firms within it, needs to be incorporated into supply chain management [2].

Energy (gas or electricity) purchased for production has seen significant price rises globally since 2002 [3]. Energy costs have increased for the European Union (EU) by 5.8% in 2012 alone and have been consistently rising on average across the EU over the past five years [4]. In the United Kingdom (UK) there has been a transition towards higher and more volatile wholesale prices of gas since 2004 [5], generating a relatively volatile retail price market. The UK has the fourth most volatile retail industrial gas and electricity price relative to EU and Organisation for Economic Co-operation and Development (OECD) countries (22 selected with data available): the standard deviation of the annual natural log of price is just under 30% for electricity and 45% for gas between 1990 and 2010 [6]. Price volatility in becoming a more consistent feature of regional gas markets and the large-scale transition to using gas as a backup fuel for stable electricity generation is increasing the volatility in demand [3]. Although gas prices have reduced considerably in

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the US from the development of unconventional gas sources [3], the limited storage capacity in the UK means that its development in the UK is unlikely to stabilise prices significantly [7]. Global demand for energy is forecast to increase substantially over the coming decades, most notably driven by emerging economies [1]. Alongside this, regional price differences in gas, and largely electricity, are forecast to be significant at least until 2035, accentuating competitive differences in the industrial bases of global economies [1].

Energy use in production chains has been thought of in terms of logistics rather than a strategic concern for the performance of the supply chain [2,8,9], as production systems have been constructed on the assumption of affordable and available energy inputs [2]. There is increasing focus now, however, on the role of energy in affecting the productivity and competitiveness of a supply chain [4,10,11]. Particular attention is given to the potential for demand side management techniques, such as energy efficiency of products and process [12], responsive consumption of energy in response to market signals through smart metering and alternative technologies [13] and also as revenue generating streams, either indirectly through the production process [14] or directly from alternative energy technologies [15]. However, these demand-side management techniques do not reduce the vulnerability of production systems to energy security: dependence on energy in the production system increases as slack is removed from the system and the relative value of energy becomes more significant [8]. Demand characteristics and dependency play a critical role in shaping the vulnerability of demand-side supply chains to the availability and affordability of energy sources [8,16].

As supply chains become increasingly complex the potential for risks to stability, disruption and efficiency increases [17,18]. The development of carbon reduction political agendas, deregulation of supply markets and rising energy costs has transformed energy into a complex and volatile commodity input, influenced by multiple markets and legislation. The security of energy as a production input is influenced by availability and affordability, often dependent on the specific characteristics of usage [16]. Energy security poses several risks to business continuity, including technological, financial and regulatory burdens from taxation schemes, pressures on margins, brand management and operations [10]. Price volatility is a particularly relevant consideration for the security of energy systems because changes in input prices generate a technical risk that can be compounded through the supply chain [16] and potentially cluster in different industrial sectors of the economy [19]. Technical risks have direct implications for the survival of individual firms and the sustainability of supply chains that come from the (in)ability of firms to manage energy prices within the chain. The impact of price volatility is also exaggerated in periods of rising prices as percentage changes equate to larger monetary values [3]. The complexity of the supply chain accentuates this risk as connections (transactions between firms) and purchasing agreements, both for supply inputs and products, shape how risk is managed and transferred along the supply chain [20,21].

The focus has been to examine aspects of energy security such as governance, responsibility, internationalisation and time, space and scale that can build an appreciation of wider system security [22,23]. Although these aspects provide an appreciation of a systems approach that extends the analysis through the supply chain and over time and space, it is limited in its incorporation of interdependency in the system between individual actors; be that firms, industries or regions. This is a distinct characteristic of demand-side supply chains. To illustrate the influence of interdependency in the use of energy as a production input a comparison of the management of metal and energy price volatility within demand-side supply chains is provided. A case study of the intermediate metal processing (IMP) industry in the West Midlands region of the UK is used to illustrate the different approaches to these commodities and the resultant risks created within supply chains. The industry produces semi-manufactured products and components for further manufacture and as such, the industry is an intermediate supplier to other manufacturers and part of extensive global production systems. In addition, the industry is a relatively large consumer of energy and therefore energy is a critical input, representing on average 8.6% of the cost base [21].

The following section outlines the methodology of the research process, followed by an overview of the intermediate metal manufacturing industry in the West Midlands, UK. A detailed overview of two of the industry's primary inputs is then provided; metal and energy. Following this, the role of energy as an input in the sustainability of supply chains is explored and finally concluding comments made.

2. Methodology

An intensive industry study was conducted from July 2009 to October 2010 on the IMP industry in the West Midlands. The industries were identified using the 2003 UK Standard Industrial Classification (SIC) code that represents the principal activities undertaken by the firm, SIC 27.5 and 28.4 for casting and forging activities respectively. A population of firms in the industry was constructed based on Companies House records of VAT registered companies and combined with additional trade registers and searches to increase the accuracy of the population (total of 153 firms), which is considered the most effective method for constructing industry populations [24]. A random sampling procedure was then undertaken to generate a sample of 45 IMP firms (29.4% of population in West Midlands, 3.8% of UK population) based on an average response rate of 61.1% throughout the study (Table 1).

In-depth qualitative interviews were conducted with operational managers at each firm (supplementary interviews were undertaken with additional firm representatives where possible), generating a total of 54 interviews of between 45 and 120 min each. Interview topics were framed by prior discussions with industry representatives from trade bodies and focussed on the challenges facing the industry, including the management of energy and metal inputs. During this stage of research it was identified that inter-firm relationships within the supply chain were significant to the management of these commodities. IMP firms experienced difficulty in managing commodity price movements independently and sought to engage their direct customers in the issue.

Case studies were used to examine causal relationships in interviews for explanatory clarity [26,27] and to examine the phenomena from another perspective [28]. A series of ten interviews were undertaken with customers and suppliers identified from the interview data that were significant trading partners to the industry, generating five direct transactional case studies (limited by data availability on trading partners) and five industry significant trading partner interviews to provide context. Due to the prominence of trading relationships identified in the first stage, case studies were used to examine these relationships and transactions, specifically exploring the transfer of risks between parties. The case studies were purposefully selected based on the significance of the relationship to the IMP firm (based on value of turnover) to provide the greatest access to these topics and trading relationships. Cross-case analysis was undertaken through matched transactions using multiple trading partners from the IMP sample where possible to increase the validity of the findings. The results are not intended to be representative but provide an exploratory analysis of the dynamics of the IMP industry and its wider supply chains around energy and commodity management.

Table 1
Sample distribution. *Source:* [25] (excludes sole proprietorships and partnerships with only owner-manager).

	Foundry (SIC 03: 27.5)			Forging (SIC 03 28.4)			IMP total
	Large (250 + employees)	Micro and SME (1–249 employees)	Total	Large (250 + employees)	Micro and SME (1–249 employees)	Total	Total
UK population	470	5	475	695	10	705	1180
Sample firms	26	2	28	14	3	17	45

3. IMP industry and production inputs

The IMP industry is energy intensive and is divided into two industries, casting and forging, specialising in the processing of metal into semi-finished products and components for further manufacture. In the UK the industry has experienced ongoing decline [29] and since 1990 there have been large scale reductions in employment and enterprise numbers in the industry across the country [30]. The West Midlands region of the UK continues to have the highest concentration of IMP firms in the country, despite also suffering one of the largest overall reductions [30]. The IMP industry is dominated by small and medium sized enterprises (SMEs) (98.7%) [25] that are highly flexible to volatile demand and reductions in enterprise numbers are predominately in large organisations (77.8% reduction in the casting industry and 33.3% in the forging) [31]. The industry is, however, a vital element of the manufacturing sector in the UK. Firms have restructured to remain competitive by providing demand responsive manufacture and services for a range of advanced manufacturing industries.

The IMP industry has three primary costs: metal, labour and energy. Metal and labour are the greatest cost components, representing 42.8% and 43.0% respectively, and although the proportion varies considerably between the two factors according to product characteristics, they are the dominate cost areas. Energy, in contrast, represents 8.6% of the cost base (ranging in individual firms from 2.5% to 20.0%). However, the energy component has more than tripled over the last decade from 2.5% in the early 2000s (Interview data, 2009–10) challenging management to try to constrain costs by acquiring energy efficient equipment or by shifting to less energy intensive products. Labour costs are inherently more stable than metal or energy as the costs are primarily regionally negotiated [32] and change over long time periods through technological and political advances [33]. Commodity input costs, such as metal and energy, can change a supply chain's cost base over very short temporal periods because of price volatility in international and national markets. Metal and energy price volatility are critical here and it is to these that we now turn our attention.

4. Metal: a commodity input

The proportional significance of metal input costs vary depending on the material type and nature of the product. IMP firms tend to specialise in either ferrous or non-ferrous based metals as they have distinct properties and therefore markets. In addition, many IMP firms have developed capabilities to manufacture components with increasingly complex metal alloys. Metal alloys have been used for a considerable period, particularly in the casting industry, however, there has been a transition towards more complex alloys such as titanium and zinc based alloys in the aerospace and structural engineering markets. Steel and aluminium alloys remain the most common materials used in IMP firms (11 firms using each material).

Specialist markets have developed to support the sale of different metals. Non-ferrous, steel and aluminium alloys are traded on global commodity markets, which set a global benchmark for all contract prices [34]. In comparison, ferrous metals tend to be purchased against a more local price [34], influenced by the local scrap market, manufacturing capacity and demand. Imports are increasingly common for the UK [35], however the price continues to be influenced by local demand characteristics. The trading of metal through global commodity markets generates a more 'ubiquitous' factor of production which reduces the competitive (dis)advantage which can be generated from it [36]. Localised pressures on material demand, availability and security influence international costs and create escalating costs, further threatening the competitiveness of manufacturing entities under different cost structures [37,38].

Metal prices are volatile. There was a considerable increase in the rate of price change in the early 1990s, which resulted in the introduction of metal surcharges. Surcharges are supplementary payments which reflect the change in price from one period to another. A base price is set between supplier and customer based on the current market price. Any movement above or below this price during a specified period is then later adjusted for through a separate payment at a series of intervals during the production agreement. The system has developed into an industry convention to protect individual firms from the potential cost of rapid input price changes (both for suppliers and customers). IMP firms have also adjusted their purchasing methods to reflect both the increased volatility in metal price and reduction in volume (due to overall fall in demand and transition towards lower volumes). Firms will typically purchase 'as and when' they need the materials for production to limit material stock and also outsource purchasing activity to generate economies of scale in pricing through combined purchase with other firms registered to the system.

The adjustments by IMP firms towards lower volumes of more specialised material products and reluctance to hold material stock has prompted significant changes in the structure of the metal supply industry, particularly in ferrous metals ([34] Table 2). IMP firms increasingly purchase from service centres, stockholders or distributers rather than directly from the mill. Mills require large schedule orders of standard products, which many IMP firms either no longer need (demand is more focussed on lower batches of specialised alloys) or are reluctant to undertake because of the volatility in prices during the length of the agreement. In the case of steel, demand from stockholders has been the greatest growth area (25%) compared to limited growth in sales direct to consumers (such as the IMP industry) (9%) (2009–10) [35]. Stockholders and service centres allow IMP firms to buy ad hoc from them for relatively low volumes and portfolios of metal products at a price premium. This allows firms to move into more specialised material products by providing low volume 'packages' of materials. The ability to purchase 'packages' of metals allows firms to engage in increasingly specialised product markets and reduces their vulnerability to price fluctuations as they do not need to buy bulk supplies.

Metal inputs are viewed by individual firms and their supply chains as a globally traded commodity, with changes in metal input costs largely out of the control of individual firms. Due to the well-publicised behaviour of metal markets (through trade journals, news broadcasts and face-to-face purchasing), for both global alloys and more localised scrap markets, there is an embedded

Table 2
Metal purchasing methods. *Source:* Adapted from [34,35,39], Interview data (2009–10).

Method	Product	General ownership structure	Implications		
			Price	Availability	Service
Mill	Standard products	Transnational corporation	Annual fixed-price contracts	Large purchases	Specified quality standards for large buyers
Stockholder	Undifferentiated products	Independent	Spot price premium for low volume	Low volume	Storage, breaking of bulk
Service centre	Customised/further processed	Outlet of mill	Spot prices	Wide product range	Further processing to tailor product to customer needs
Merchant	Recycled (scrap)	Independent	Influenced by local market prices	Dependent on local markets and monopoly buyers	Quality and metal grade varies
Distributer	Imported metal	Transnational corporation or outlet of mill	International market prices	Large purchases	Access to mill products through spot prices

understanding that price volatility needs to be managed through the entire supply chain. As such, conventions have developed, particularly the use of the surcharge system, to transfer additional costs up the supply chain protecting the interests of the intermediate suppliers of metal parts. The following section will explore the characteristics of energy as a production input.

5. Energy: a semi-commodity input?

Energy usage in the industry has reduced dramatically since 1990 (63.5% and 37.4% in the casting and forging industries respectively) and to a far greater degree than the manufacturing average (13.7%) [40]. This reduction is a result of several factors: changes in production demand, efficiency improvements and product characteristics. Energy use and production volume has a non-linear relationship in the IMP industry: as production volumes reduce there is not a proportional drop in energy use. The casting industry has actually increased its specific energy consumption (SEC) (energy used per tonne of product produced) between 2002 and 2010 [41]. The transition to small production batches and greater product mix in the production system has reduced the energy efficiency of the process, combined with more advanced product and material characteristics that can require additional energy use during processing. Despite these requirements, there is a continual focus on reducing energy usage to reduce the aggregate cost base and investment has been undertaken in the IMP industry, particularly the forging industry, to address this.

Energy is a complex production input due to the multiple market influences on its price and availability [7,42]. As an input, energy has three direct influences on its cost: market price, legislation and purchasing options. The retail market price for industrial energy users in the UK has changed in two fundamental ways since the early 2000s: prices are rising and becoming increasingly volatile. The price of energy has increased significantly over the last decade (1998–2008) [43]. Increases in industrial energy prices are forecast to continue [44], particularly for large industrial users [45] and SMEs who are less flexible in the way they purchase energy [46]. In addition, prices are also becoming more volatile. The rate of change in price has increased both in magnitude and tempo over the last decade [43] and volatility has become a consistent feature [47].

Large industrial energy users are susceptible to additional regulations aimed at reducing energy related carbon emissions through tax-based deterrents or limitations in quantity through permit allocation [45]. Legislations to reduce carbon emissions are devised according to the level of energy usage and specific target reduction mechanisms installed at the sectoral level of the economy. In addition, suppliers are required to purchase a proportion of their electricity from renewable sources, which are generally more expensive. The primary mechanism that affects IMP firms directly is the Climate Change Levy (CCL), which is aimed at large industrial consumers as an additional tax on energy consumption. The CCL is a tax paid through energy supply bills to encourage the decarbonisation of industry. This is a UK based tax targeted at large energy users, which has added an average additional cost of 3.5% and 3.6% to electricity and gas bills (correct at Q3 2010) [48]. The CCL has an associated subsidy policy, the Climate Change Agreement (CCA), which reimburses up to 80% of the tax if efficiency savings have been made. European and national taxation and subsidy policies can be applied to the market price, resulting in greater spatial difference between actual purchase prices paid by industrial users [49–52]. The additional policies surrounding such taxes (such as the CCA and direct reinvestment into the sector through interest-free loans) reduce the actual cost impact. These policies are set to be reduced from 2013, which will increase the competitive disadvantage felt by large energy consuming industries in the UK [44].

The purchasing methods used by IMP firms are a significant factor in determining the energy cost component. Denationalisation of UK energy markets has allowed increased competition in the market and as a result, greater variety of purchasing methods (Table 3). The retail market has responded to the increased volatility in prices by introducing greater variety of supply options to industrial users to capitalise on the buyers' desire to reduce this particular cost component. Management currently purchases energy by selecting from three available strategies outlined in Table 3.

Within these purchasing methods the denationalisation of the retail market has generated a greater variety of options to increase the flexibility in energy supply to industrial customers (see Table 4). These are primarily related to the development of flexible contracts. Despite this, fixed term contracts remain the most common energy purchasing methods employed by IMP firms (18 firms). This is primarily due to the knowledge and time commitment required to manage more flexible purchasing, which is largely outside the capabilities of IMP firms. Energy brokers are increasingly utilised by buyers as a means of generating the most suitable and advantageous supply structure (10 firms). Brokers act as intermediaries between energy suppliers and users, providing guidance on the most suitable form of purchase across the market.

6. Discussion: sustainable supply chains and energy as a production input

The use of energy as a factor of production has changed. Demand side supply chains are increasingly complex, with manufacture deconstructed and split between many organisations. As such,

Table 3
Purchasing strategies.

Strategy	Description
Spot buying through the retail market	One-off payments for discrete quantities at the point of use
Forward contracts through the retail market	Pre-agreed rates for a specified quantity over a specified period (these contracts usually have a cheaper unit price as they allow energy suppliers to plan for demand)
Wholesale purchase	Very large users are able to directly purchase from the wholesale market, eliminating the retailers margin

the interaction between suppliers in the chain is a vital aspect of supply chain management [58]. Supply chain management (SCM) debates highlight the importance of supply chain competitiveness, rather than the individual firm [59–61]. SCM integrates strategic purchasing and supply integration to deliver competitive advantages to the overall supply chain and both customers and suppliers within it. Strategic purchasing has a direct and considerable impact on supply chain performance as purchased supplies generally represent a large proportion of production costs [62]. Supply integration, through closer and socially embedded relationships, allows for communication between firms and the accumulation of knowledge of supply markets in customer firms [63]. Uncertainty in the chain, from increased complexity and dynamism, can negatively impact on firm performance if risks are not manageable. For management it is critical that the supply chain is considered as a whole, through strategic purchasing and supplier integration, so that uncertainty can be reduced and threats to the sustainability of the supply chain identified [58,59]. The key management challenge is to try to enhance certainty through strategic purchasing of a volatile input. One solution is the adoption or development of new energy efficient equipment and also process improvements. It is also possible to capture waste heat and transform it into a resource that can be used within the factory or sold. A key consideration is the development of a new approach to energy volatility that enables firms to transfer price increases onto end-users. This would require co-operation between firms and also the development of new forms of contractual relationship between IMP firms and their customers. Customers will resist as the current approach benefits them, but disadvantages IMP firms. In the long term a sustainable solution must be developed as the IMP firms play a critical role in advanced manufacturing supply chains. This solution may develop through the creation of new industry conventions regarding sharing the risks associated with energy volatility and security. If an industry solution does not develop then Government may have to intervene to ensure the survival of the IPM industry in the UK.

Metal as an input is currently managed through the supply chain by purchasing inputs in discrete batches or by the final manufacturer for the production chain. Price changes associated with these purchases can then be identified and transferred through the chain to form an accurate costing at the end user. Energy is purchased as an input by individual firms, under the planning and management responsibility of the purchasing firm. However, the risks and use of energy requires management throughout the chain. Price volatility can have a significant effect on the cost of energy inputs depending on the timing and type of purchase made. Although the individual firm can influence this and their ability to negotiate or find a deal is critical, the overall price movements and the expertise required for this are outside the usual capability or capacity of an individual firm. This price uncertainty generates a risk to firms and their supply chains. Profit margins in the IMP industry are extremely low, on average 2.5% across sampled firms (range from −11.2% to 17%) and therefore energy price volatility has the potential to wipe out profits and turn profitable orders into unprofitable ones. As such, the ability to transfer the technical risk (derived from the movement in cost that is unrelated to usage in the production process and therefore the firm's direct management) is a critical element of firm survival and management of energy as an input throughout the supply chain. Purchasing of energy and interaction between firms in the chain are critical aspects of the sustainability of demand side supply chains.

6.1. Purchasing

The purchasing options available for large scale industrial energy have altered in three fundamental ways. First, the timing of contract purchases has changed. Traditionally, all large industrial

Table 4
Energy purchasing methods. *Source:* [53–57], Interview data (2009–10).

Current purchasing methods (2009–10)		Number of firms using
Method	Reasons for use	
Multi-year fixed price contracts	Increased volatility in the market abated by fixing prices for longer periods Premium paid to supplier to transfer risk of price changes to the supplier Uniform volume usage within set minimum and maximum values	18
Flexible contracts	Increased volatility in the market can be abated by purchasing blocks of energy, combining with spot price purchasing and purchasing staggered over time to hedge risk Customer manages risk of price fluctuations Set minimum and maximum volumes over contract period	4
Spot buying (short dated buying e.g. day-ahead, month-ahead)	To avoid locking into a contract at a high point Prices usually significantly higher than contract prices[a]	3
Direct from wholesaler	Available for large users to remove retailers overhead Increased financial and volume risk to customer from additional set up costs and volume requirements in market	1
Energy traders/agents	Able to advise and manage energy purchasing and trading on customers behalf to generate a more complex purchasing pattern than customers could independently manage Additional cost from traders margin	10

[a] Dependent on timing of contract and market fluctuations as spot-prices reflect point-in-time (half-hour blocks) prices rather than temporally independent prices in contracts.

users would generally purchase annual fixed price contracts at a set period during the year (around 1st October). With significant increase in price volatility, the timing of forward contract purchasing has become extremely important in determining competitive (dis)advantages: firms can potentially buy energy at a considerably higher or lower price than their domestic competitors based solely on the timing of purchase. As a result, forward contract purchasing now occurs throughout the year to (hopefully) optimise or spread the timing of the lock-in price. The second change is related to the length of contracts. Again, traditionally, an annual fixed price contract would be purchased. Due to volatility in prices the retail market now provides variable contract lengths. Extended contracts (up to 5 years) are increasingly available, which allows industrial users to forward plan their energy cost and mitigate their risk to unplanned price changes from market volatility. The retail provider charges a price premium to cover the risk of any short term losses they may be susceptible to. The third alteration has been the transfer of the risk of price changes from the retail market supplier to the purchasing firm. The retail market now offers flexible contracts, which allow staggered purchasing of blocks of energy, spot buying, direct trading on the wholesale market or a combination of these, to allow purchasing firms to manage their own risk to commodity price changes.

Through these three changes, the risk of energy price volatility is largely the responsibility of individual purchasing firms to manage through creative buying to suit production demand. Contra to metal supply markets, the transition in energy supply markets is to extend the temporal commitment of the purchasing firm rather than reduce future obligations. Differentiated supply options have provided increased flexibility to industrial consumers but to optimise this flexibility the firm needs to be extremely knowledgeable in energy markets and commodity purchasing – skills not traditionally required in production industries. As such, only a limited number of the firms have undertaken flexible contracts or direct wholesale trading. This approach is attractive as it has the potential to reduce energy costs through optimal purchase timing and without the retailer's price premium of a fixed-price contract. The risks are considerable and large financial losses can occur if energy demand is not, or cannot, be accurately forecast. In forward contracts (both fixed-price and, increasingly, flexible) usage volumes are predefined within a range (minimum and maximum usage clause) and usage outside these volume tolerances generates penalties (including the ongoing commitment to purchase the stated volume of energy) and a far more expensive unit price beyond the agreed limit.

Purchasing behaviour has the potential to generate significant differences in unit energy prices between both competitors and other firms in the supply chain. Essentially, all firms in the supply chain are likely to be paying a different, and perhaps vastly different, price for energy. Without the transfer of prices between buyers and suppliers, this differentiation is not diluted between firms and some firms will face substantially higher unit prices that threaten their stability and some firms will have competitively low prices. Purchasing capabilities generates vast differences in prices and sites the technical risk of price changes with the individual buying firm, as they hold the supply contract with the energy provider.

6.2. Industry conventions

The embedded understanding of the supply chain has played a critical part in determining 'industry norms' [64] and the capacity for firms to transfer price increases through the chain. This is particularly highlighted by the acceptance of metal, and not energy, as a commodity input with volatile market prices. Transferring energy price movements to customers is a critical aspect of managing technical price risk and therefore interactions between firms in the supply chain are a vital element of risk management. The nature of the transaction between parties enables or inhibits the transfer of price movements forward to customers in the chain. Price escalators, either at set periods or at the completion of the order, are a common mechanism to limit the impact of metal price volatility on individual firms. The usage in the case of energy is far more limited and under the discretion of individual customers rather than an established practice [21]. Energy price escalators are not usually included in formal agreements (contracts) for orders, despite all production orders usually including metal price escalators as standard. This is a direct result of the perception of energy inputs as solely the responsibility of the individual firm rather than the supply chain to manage effectively.

The transfer of energy price changes is beginning to be an established practice in other sectors of the economy (for example see [65] webpage). The surcharge method is used successfully primarily in heavy industries such as basic metal production, cement and chemicals, particularly glass manufacture. These are energy intensive industries (EII), determined by the ratio of energy costs to gross value added exceeding 15% [52] and therefore have a relatively high proportion of their cost base from energy. In addition, these are foundation industries, dominated by large organisations with some market concentration, where the practices of key firms in the industry drive the development of new conventions. Recent government support in the UK [44] has highlighted the significance of energy costs and increased visibility around these industries.

The problem of technical risks from energy price fluctuations is now encroaching on mid-level industrial energy consumers, such as light and medium engineering industries like the IMP, because of the scale of price rises and volatility. Energy has traditionally been managed as part of the aggregate cost base in these sectors because it represented a relatively low proportion. As such, the conventions in the industry view the responsibility of energy management with the individual firm and based around process efficiency. The IMP industry is an intermediate supplier and dominated by SMEs, and therefore has far lower visibility. Although the industry's energy consumption is high compared to the wider economy, it is not directly classified as an EII in current government policy. The limited visibility of light- and medium-engineering industries in general, both in the economy and the supply chain, limits their capacity to transfer energy cost increases. But the risk remains for the supply chain. These sectors undertake vital processes and their stability is a key factor in the wider chains competitiveness. The management of energy by the individual firm reduces profitability for the firm but a sustained neglect of the risk by the supply chain limits the competitiveness and security of the chains they are part of.

7. Conclusion

The use of energy in the wider economy is of vital significance to growth, economic competitiveness, development and a sustainable economic system. Energy is an input, both directly in production and indirectly through supply chain logistics, and therefore the price needs to be manageable or controllable so that it provides firms with some certainty over cost and availability. Current conceptualisations of energy as a nominal factor input addressed through investment in efficiency [12,66,67] do not take into account the complexity of the way energy is used in manufacture. Demand side supply chains are changing; they are demand responsive, complex and interrelated and as such require flexibility in purchasing inputs and adjustments to product costings. Energy remains inflexible as an input, a result of both purchasing options and embedded understandings in the production supply chain. This inflexibility generates distinct risks to the individual production firm and therefore the sustainability of the wider supply chain. The management capacity for technical price risks by the individual firm is limited because of the interdependency between trading partners in the supply chain. Continuity in production systems requires an integrated management approach within the supply chain.

Effective purchasing at the firm level can reduce the firm's vulnerability to price movements but commodity price movements are outside the control of the individual firm. The acceptance of metal price movements and the convention of surcharge mechanisms to manage these price movements through the production chain are in stark contrast to energy management practices. This illustrates that some key inputs have more significant and differentiated impacts on different firm's performance in the chain. The risk posed from the inability to transfer price movements to sales prices in the chain illustrates the role of interdependency between firms in demand-side supply chains. The competitiveness and profitability of production contracts is directly influenced by short-term energy price movements. Although energy represents below 10% of sales prices on average across the industry, these practices over time erode profitability and long-term stability. The effects are compounded through the supply chain over time (from loss of competitiveness due to price changes and rises) as actors at multiple spatial scales influence the nature and impact of price risk at the individual firm and wider supply chain. The interdependency between actors in the supply chain is a critical aspect in the management of price risks from energy and needs to be incorporated into understandings of energy security.

The findings presented illustrate that the security of energy impacts different stakeholders in different ways. Prices paid for energy are highly influenced by the timing and type of purchase, potentially generating vastly different energy input prices throughout the chain. The management of energy at the individual firm level penalises firms that are undertaking energy-intensive aspects of production, as they face additional levies and the risks associated with energy volatility. The magnitude of price volatility has forced more industries to adjust to technical price risks from energy and rendered management of energy costs beyond the capability of the individual small and medium-sized enterprise. The supply chain is increasingly responsible for the management of energy price changes although is reluctant to accept this responsibility. This management is in the form of sophisticated procurement: joint management of energy inputs from purchase, usage and transfer through the supply chain to the final point of manufacture.

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References

[1] IEA. World Energy Outlook 2013 – Executive summary. France: International Energy Agency; 2013.
[2] Halldórsson A, Kovács G. The sustainable agenda and energy efficiency: logistics solutions and supply chains in times of climate change. Int J Phys Distrib Log Manage 2010;40(1/2):5–13.
[3] van der Hoeven M. Energy price volatility in fossil fuel markets. In: G20 Mexico Summit 2012: The Quest for Growth and Stability 2012. Newsdesk Media Group and the G20 Research Group. University of Toronto; 2012. p. 122–3.
[4] EC. Member States' competiveness: performance and implementation of EU industrial policy. Industrial performance scoreboard. In: Europe 2020 initiative, Directorate-General for Enterprise and Industry, Editor 2013, European Commission; 2013.
[5] DECC. Estimated impacts of energy and climate change policies on energy prices and bills. Department of Energy and Climate Change (DECC). London; 2013. p. 97.
[6] London Economics. Energy retail markets comparability study: a report for DECC, London; 2012.
[7] Alterman S. Natural gas price volatility in the UK and North America. In: Country and Regional Studies 2012. The Oxford Institute for Energy Studies, Oxford; 2012.
[8] Hoggett R, Eyre N, Keay M. Energy demand and energy security. In: ESMW closing conference 2012. The Royal Society, London; 2012.
[9] Rudberg M, Waldemarsson M, Lidestam H. Strategic perspectives on energy management: a case study in the process industry. Appl Energy 2013;104:487–96.
[10] Froggatt, Lahn G. Sustainable energy security: strategic risks and opportunities for business, Lloyd's 360 Risk Insight, 2010, Chatham House; 2010.
[11] Ali Ahmed HJ, Bashar OHMN, Wadud IKMM. The transitory and permanent volatility of oil prices: what implications are there for the US industrial production? Appl Energy 2012;92:447–55.
[12] Thollander P, Dotzauer E. An energy efficiency program for Swedish industrial small- and medium-sized enterprises. J Clean Prod 2010;18(13):1339–46.
[13] Awudu I, Zhang J. Stochastic production planning for a biofuel supply chain under demand and price uncertainties. Appl Energy 2013;103:189–96.
[14] Waldemarsson M, Lidestam H, Rudberg M. Including energy in supply chain planning at a pulp company. Appl Energy 2013;112:1056–65.
[15] Kostka G, Polzin C, Scharrer J. The future of sugar cane in (the) People's Republic of China and India – Supply constraints and expansion potential. Appl Energy 2009; 86(Supplement 1(0)): S100–7.
[16] Winzer C. Conceptualizing energy security. Energy Policy 2012;46:36–48.
[17] Carter CR, Rogers DS. A framework of sustainable supply chain management: moving toward new theory. Int J Phys Distrib Log Manage 2008;38(5):360–87.
[18] Brindley C, Ritchie B. Introduction. In: Supply Chain Risk. In: Brindley C, editor. Hampshire (England)/Burlington (USA): Ashgate; 2004. p. 3–13.
[19] Knight ERW. The economic geography of European carbon market trading. J Econ Geogr 2011;11(5):817–41.
[20] Harland C, Brenchley R, Walker H. Risk in supply networks. J Purchas Supp Manage 2003;9(2):51–62.
[21] Mulhall RA, Bryson JR. The energy hot potato and governance of value chains: power, risk, and organizational adjustment in intermediate manufacturing firms. Econ Geogr 2013;89(4).
[22] Barrett M, et al., Energy security in a multipolar world: discussion paper. In: Energy Security in a Multipolar World 2010. University of Exeter; 2010. p. 22.
[23] Mitchell C, Watson J. Introduction: conceptualising energy security. In: New challenges in energy security: the UK in a multipolar world. In: Mitchell C, Watson J, Whiting J, editors. Basingstoke: Palgrave MacMillan; 2013. p. 1–21.
[24] BERR. BERR Summary: ONS – UK Company Statistics Reconciliation Project. Department for Business Enterprise and Regulatory Reform; 2009.
[25] BIS. SME Statistics for the UK and Regions 2010. Department for Business Innovation & Skills; 2010.
[26] Yin RK. Case study research: design and methods, 3rd ed. Sage; Thousand Oaks (London); 2003. p. 181.
[27] Yin RK. Applications of case study research. Thousand Oaks (London): Sage; 2003. p. 173.
[28] Chetty S. The case study method for research in small-and medium-sized firms. Int Small Bus J 1996;15(1):73–85.
[29] Massey D, Meegan R. The anatomy of job loss: the how, why and where of employment decline. London & New York: Methuen; 1982.
[30] Eurostat. Structural Business Statistics: Multi Yearly Regional Statistics (NUTS 06). European Commission; 2011.
[31] Eurostat. Structural business statistics: annual detailed enterprise statistics on manufacturing subections DF-DN and total manufacturing (NACE Rev. 1.1 D). European Commission; 2011.
[32] Christopherson S, Clark J. Remaking regional economies: power, labor, and firm strategies in the knowledge economy. Studies in economic geography. London and New York: Routledge; 2007. p. 169.
[33] Bluestone B, Harrison B. The deindustrialization of america: plant closings, community abandonment, and the dismantling of basic industry. New York; 1982: Basic Books; 1982.
[34] Cockerill T. Metals, in industries in Europe: competition, trends and policy issues. In: Johnson PS, editor. Cheltenham: Edward Elgar Publishing Limited; 2003.
[35] ISSB. UK Steel Mill Deliveries. The Iron and Steel Statistics Bureau; 2011.
[36] Maskell P, Malmberg A. The Competitiveness of firms and regions. Eur Urban Region Stud 1999;6(1):9–25.
[37] Kalafsky RV. An examination of the challenges of charlotte manufacturers. Prof Geogr 2007;59(3):334–43.
[38] Leonard JA. How structural costs imposed on US manufacturers harm workers and threaten competitiveness. Washington: National Association of Manufacturers; 2003.
[39] Ahlbrandt RS, Fruehan RJ, Giarratani F. The renaissance of American steel: lessons for managers in competitor industries. New York & Oxford: Oxford University Press; 1996.
[40] ONS. Energy Consumption in the UK: Industrial Data Tables (1990–2010). Department of Energy & Climate Change, Office for National Statistics; 2010.
[41] CTI. Sector performance record. Castings Technology International. Personal Communication; 2010.
[42] Stern J. Security of European natural gas supplies: the impact of import dependence and liberalization. In: Sustainable development programme 2002. London: Royal Institute of International Affairs; 2002.
[43] DECC. Industrial energy prices. Department of Energy & Climate Change; 2010.

[44] HMT. Autumn Statement 2011. HM Treasury. The Statement Office; 2011.
[45] DECC. Planning our electric future: a white paper for secure, affordable and low-carbon electricity. Department of Energy & Climate Change; 2011.
[46] HC. Ofgem's retail market review: sixth report of session 2010–12. House of Commons, Energy & Climate Change Committee, London; 2011.
[47] Jones C. Less and less favoured? Britain's regions in the energy crunch. Environ Plan A 2010;42:3006–22.
[48] ONS. Quarterly energy prices: December, Department of Energy and Climate Change, Editor 2010, Office for National Statistics; 2010.
[49] EC. DG competition report on energy sector inquiry. European Commission; 2007.
[50] London Economics. Structure and performance of six European wholesale electricty markets in 2003, 2004 and 2005. European Commission; 2007.
[51] Haley CV, Haley GT. Subsidies and the China Price. Harvard Business Review; 2008. p. 25–6 [June].
[52] ICF. An international comparison of energy and climate change policies impacting energy intensive industries in selected countries: Final report. Department for Business Innovation & Skills. London; 2012.
[53] Exchange U. Energy Procurement; 2007.
[54] A game of risk. In: The Manufacturer; 2004.
[55] Purchasing Pain. In: The Manufacturer; 2006.
[56] Accounting for energy. In: The Manufacturer; 2010.
[57] Power broking – Energy purchasing strategies explored. In: The Manufacturer; 2011.
[58] Kraljic P. Purchasing must become supply management. Harvard Business Review; 1983. p. 109–17 [September–October].
[59] Li S et al. The impact of supply chain management practices on competitive advantage and organizational performance. Omega 2006;34(2):107–24.
[60] Chen IJ, Paulraj A. Understanding supply chain management: critical research and a theoretical framework. Int J Prod Res 2004;42(1):131–63.
[61] Ketchen Jr DJ, Giunipero LC. The intersection of strategic management and supply chain management. Ind Mark Manage 2004;33(1):51–6.
[62] Chen IJ, Paulraj A, Lado AA. Strategic purchasing, supply management, and firm performance. J Oper Manage 2004;22(5):505–23.
[63] Bernardes ES, Zsidisin GA. An examination of strategic supply management benefits and performance implications. J Purchas Supp Manage 2008;14(4):209–19.
[64] Storper M. The Regional World: territorial development in a global economy. Perspectives on economic change. In: Gertler MS, Dicken P, editors. New York and London: The Guildford Press; 1997.
[65] Pilkington. The pilkington building products energy surcharge. Available from: <http://www.pilkington.com/en-gb/uk/trade-customers/energysurcharge> [29 July 2013].
[66] Thollander P, Ottosson M. Energy management practices in Swedish energy-intensive industries. J Clean Prod 2010;18(12):1125–33.
[67] Worrell E et al. Industrial energy efficiency and climate change mitigation. Energ Effi 2009;2(2):109–23.